The role of the GCOS Reference Upper-air Network (GRUAN) in climate research

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What is GRUAN?

The Global Climate Observing System (GCOS) Reference Upper-Air Network (GRUAN) is an international observing network, designed to meet climate requirements and to fill a major void in the current global observing system by providing reference observations. GRUAN is envisaged as a network of 30-40 sites building, where possible, on existing observational networks and capabilities (Fig. 1 and 2).

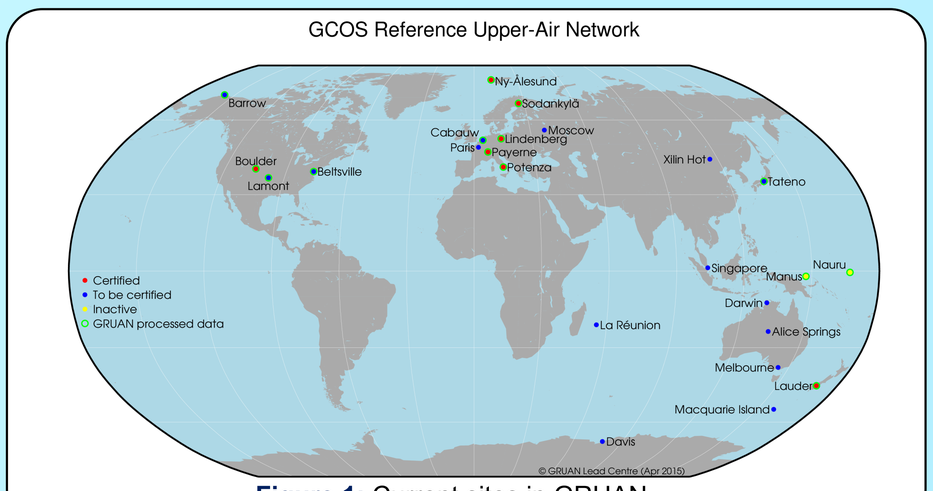

Figure 1: Current sites in GRUAN

GRUAN as part of a system of systems observing architecture

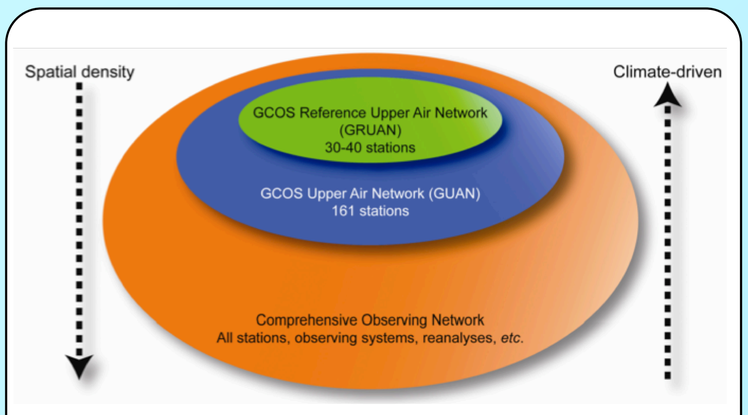

Figure 2: GRUAN is intended to serve as a reference network which consists of well instrumented and well understood sites.

GRUAN RS92 radiosonde data product

- **Tailored GRUAN data processing has been developed to correct temperature, pressure, humidity, and wind profiles for all known systematic biases and to generate vertically resolved estimates of the measurement random uncertainties (Dirksen et al. 2014).**
- **The dominant source of RS92 measurement errors is solar radiation, which causes temperature warm biases (partially compensated by ventilation) and humidity dry biases (Fig. 5).**
- **Corrections for radiation-related biases, and their uncertainties, are based on the results of experiments made at the GRUAN Lead Centre.**
- **Availability of the GRUAN RS92 radiosonde data product is shown in Fig.4.**

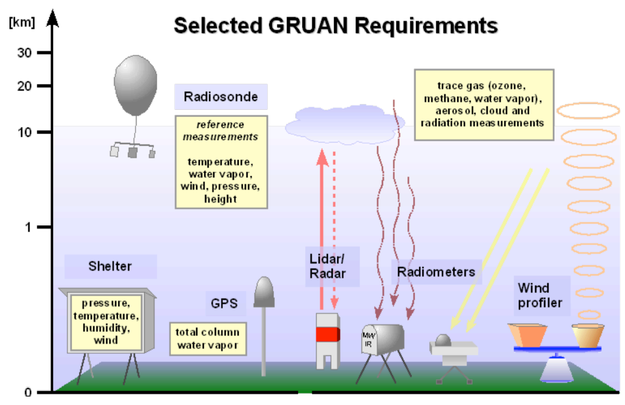

Figure 3: Schematic diagram showing some required measurements for a generic GRUAN site.

Partners

- **National contributors (fundamental to success of the enterprise)**
- **The Global Space-based Inter-calibration System (GSICS) and the Sustained, Coordinated Processing of Environmental Satellite Data for Climate Monitoring (SCOPE-CM) Initiative**
- **WMO; its Commission for Instruments and Methods of Observations (CIMO); Commission on Climatology (CCl); Commission for Basic Systems (CBS); The World Climate Research Programme (WCRP)**
- **Existing observational networks (NDACC, ARM, GAW, BSRN, GUAN, GSN)**

A GRUAN reference observation

- ✓ **Is traceable to an SI unit or an accepted standard**
- ✓ **Provides a comprehensive uncertainty analysis**
- ✓ **Maintains all raw data**
- ✓ **Includes complete meta data description**
- ✓ **Is documented in accessible literature**
- ✓ **Is validated (e.g. by intercomparison or redundant observations)**

Other products in development

- **Additional radiosondes: Modem. Meteolabor, Mesei.**
- **Water vapour profiles from high-resolution chilled-mirror frost point temperature measurements.**
- **Ground-based Global Navigation Satellite Systems (GNSS) total column water vapour.**
- **Lidar measurements of temperature, ozone and water vapour profiles**
- **Data products from FTS (Fourier Transform Spectroscopy) including water vapour, methane, carbon dioxide and ozone.**
- **Microwave radiometer (MWR) observations of temperature and water vapour profiles, total column water vapour and total cloud liquid water.**

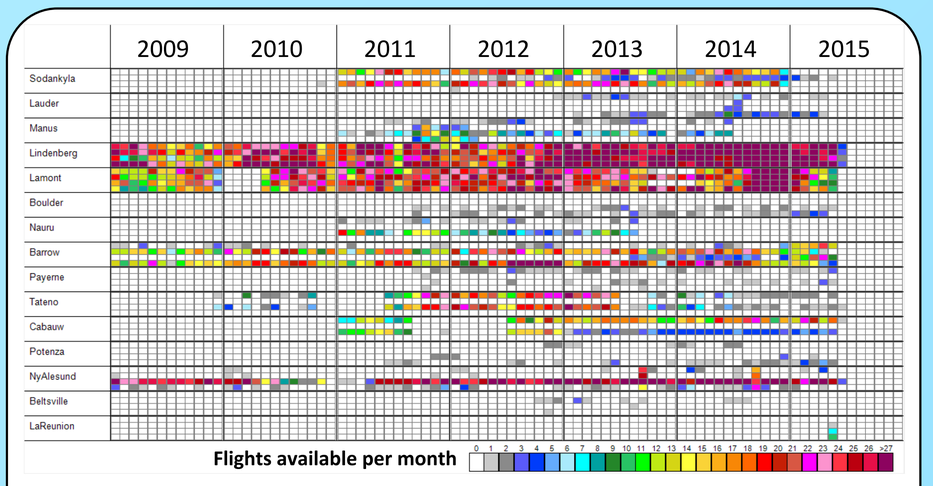

Figure 4: Availability of RS92 radiosonde data from across GRUAN. Each row for each site shows the data availability in 6 hour periods i.e. 00:00-06:00, 06:00-12:00, 12:00-18:00 and 18:00-24:00.

Getting involved in GRUAN

The primary point of contact is the Lead Centre through gruan.lc@gruan.org. Sites wishing to enter the network are encouraged to contact the Lead Centre. Scientists wishing to contribute to the network development and understanding can join one of several task teams or initiate a project under the science coordinators. Using GRUAN data benefits both GRUAN and your science. Please let us know if you undertake published work using the data and provide constructive feedback.

Research in support of GRUAN operations

- **It is imperative for GRUAN's operations to be founded on research published in the peer-reviewer literature for scrutiny by the global community. Some examples:**
- **Solar radiation-induced biases in radiosonde measurements have been assessed in Philipona et al. (2012).**
- **Correction schemes developed for RS92 radiosonde data products have proven useful for developing correction methods for historical radiosonde data (Wang et al. 2013) and validating pre-flight corrections applied in the Vaisala ground-station software (Yu et al. 2015).**
- **Whiteman et al. (2011) investigated time to detect water vapour trends at ~200 hPa. Conclusion: at best it would take at least 12 years of daily observations at the Southern Great Plains site in northern Oklahoma.**
- **Fassò et al. (2014) established statistical basis for understanding extent to which collocation uncertainty is related to environmental factors.**
- **Madonna et al. (2014) provided criteria to quantify the value of complementary measurements and assess how measurement uncertainty is reduced by measurement complementarity.**

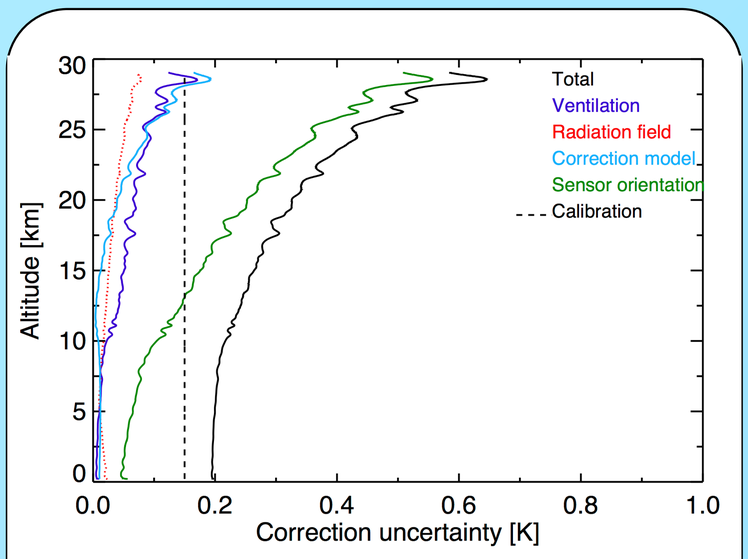

Figure 5: Contributions of the various uncertainty terms to the total uncertainty estimate of the GRUAN temperature correction for a specific sounding performed at Lindenberg on 27 September 2013 (from Dirksen et al., 2014). The total uncertainty is the geometric sum of the squared individual uncertainties. The correction model is the estimated vertically resolved error on the temperature based on the estimated actinic flux. This error is subtracted from the measured temperature profile to produce the corrected ambient temperature.

Literature

- Bodeker, G. E. et al., Reference upper-air observations for climate: From concept to reality. *Bull. Amer. Met. Soc.* In press.
- Dirksen, R.J. et al., Reference quality upper-air measurements: GRUAN data processing for the Vaisala RS92 radiosonde. *Atmos. Meas. Tech.*, 7, 4463-4490, doi: 10.5194/amt-7-4463-2014. **2014.**
- GCOS-170, The GCOS Upper-Air Reference Network (GRUAN) Manual, **2013**.
- GCOS-171, The GCOS Upper-Air Reference Network (GRUAN) Guide to Operations, **2013**.
- Immler, F.J. et al., Reference Quality Upper-Air Measurements: guidance for developing GRUAN data products. *Atmos. Meas. Tech.*, 3, 1217–1231, doi:10.5194/ amt-3-1217-2010, **2010**.
- Philipona, R. et al., Solar and thermal radiation profiles and radiative forcing measured through the atmosphere. Geophys. Res. Lett., 39, L13806, doi: 10.1029/2012GL052087, **2012**.
- Wang, J. et al., Radiation dry bias correction of Vaisala RS92 humidity data and its impacts on historical radiosonde data. J. Atmos. Oceanic Technol., 30, 197-214, doi:10.1175/jtech-d-12-00113.1, **2013**.
- Whiteman, et al., The relative importance of random error and observation frequency in detecting trends in upper tropospheric water vapor. J. Geophys. Res., 116, D21118, doi: 21110.21029/22011JD016610.
- Yu, H. et al., Evaluation of humidity correction methods for Vaisala RS92 tropical sounding data. J. Atmos. Oceanic, Technol., 32, 397-411, doi:10.1175/jtech-d-14-00166.1, **2015**.